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Advanced Progressive Road Network Diagnostics Method Used to Monitor Changes in the Quality of the Pavement Surface

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Abstract

The surface properties of pavements are a basic factor of their serviceability and one of the most important factors of their safety. For the prediction reasons of incoming reconstructions, repairs or any services, it is very important to know the development of particular parameters of surface properties in dependence on the traffic load and time aspect. An important factor of the road quality, firstly by asphalt pavements, is a transverse evenness expressed by ruts depth and skid resistance characterized by friction coefficient. In order to determine the development, these factors were analyzed the measurements of test sections on the highway and selected roads of first and second class every year. Constantly exchanging values of data, deficiencies in data collection, but also in the process of evaluation suggest to the need for further research. Within the Research Center of the University of Žilina, people are dealing with scanning of the pavement surface in order to monitor the individual parameters of pavement serviceability. This paper deals with the creation, analysis and evaluation of a 3D road surface model in terms of two properties of pavement serviceability – the rut depth and its texture. Measurements are realized on an experimental field with accelerated straining on the pavement-loading wheel. The long-term accent should be mentioned predictions functions of selected pavement serviceability parameters.

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1. Introduction

A requirement for quality and safe road infrastructure resonates at present more frequently considering the obligations of EU member states to reduce the number of accidents and fatalities on the roads. Pavement diagnostics, together with the collection of traffic data and updating process of current database of the road network, is the main input of pavement management processes (PMS). It is the most challenging process of the entire PMS in terms of financial, time, technological and personnel resources. As new technologies arise, they entail not only the simplification the data collection process but also increase in quality of measurement results and even measurement of data, which were previously possible to obtain only through destructive methods. The ability to measure more parameters, measure them faster, more accurately and safely, enables us to obtain the desired volume of data needed for complex PMS decision-making processes - estimation of optimal intervention time and choosing of optimal technology for maintenance repair and rehabilitation. This article is focused on the collection of data regarding pavement's surface using the interpretation and collection of data regarding the quality of road surface by scanning its surface with a laser beam. Transport is a complex technical and multidisciplinary process that creates a series of scientific knowledge and context [5, 6, 7].

1. Testing Field and Measurement Equipment

Our department - Research centre carries out measurements in the experimental field. Research Centre of the University of Žilina is a unique research and development facility established in 2013 at the University of Žilina. Its mission is to achieve synergic effect in using and enhancing research potential by integrating crucial research activities as Regional Centre for applied research. Its primary goal is to create the environment encouraging acceleration and integration of innovative research activities of the University of Žilina working places and the swift implementation and commercialization of research outcomes, which will directly contribute to economy competitiveness increase of Žilina region, as well as the Euro-region Beskydy and regional disparities decrease throughout the whole Slovak republic.

In addition, the new innovative high-tech small and medium sized spin-off companies will be established, new jobs in research and development especially for young researchers and postgraduates will be created and conditions for educational process at the University of Žilina will be improved. While primary task is to perform excellent applied research for industrial use, Research Centre focuses especially on research impact on everyday life. Research Centre plans to perform research for people. Within the Research centre, we dispose of an experimental test field.

The test field has a length of 6 meters and a width of 2.2 meters. The pavement structure was designed as a pavement for a road with traffic load class TLC III. It is a flexible pavement with bitumen concrete surfacing.

The wearing base layer is made of asphalt concrete (AC) 11; CA 35/50; 40 mm thick. The base course layer is made of asphalt concrete (AC) 16 P, CA 35/50; 80 mm thick. The road base is a mechanically bound aggregate MSK 31.5 GB; 180 mm thick. Sub-base is gravel ŠD; 31.5 (45) GC; 200 mm thick.



Fig. 1 Experimental field.

The laser scanning technology allows focusing in detail on the pavement surface and it is near surroundings in a coordinate system. In many cases, it is a more detailed measurement than it is provided by other technologies. Among other advantages of this method, a self-moving can be included, which does not need any other external mechanisms that can make scanning remote surfaces difficult and thereby negatively affect the measurement itself. The system allows free movement of the object during scanning. It is also possible to see an image of the scanned surface in real time. On the test field (Fig. 1) measurements using a smaller type of hand-held 3D scanner- ZScanner 800 (Fig. 2) with a maximum resolution of 0.1 mm were realized. The disadvantage of handheld equipment is time-consuming measurement and the evaluation.

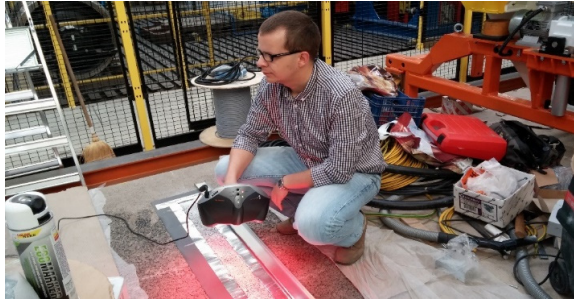


Fig. 2 3D hand scanner.

2. Transverse Evenness

The evaluation of evenness road in transversal direction consists in measurement of transverse evenness as aberrance from theoretical condition. For this reason, it is important to differentiate these two basic terms in terminology. Transverse road evenness is unevenness of road surface in vertical direction on the traffic direction. It is expressed as the difference between existing and theoretical transversal profile of road. The measurement and evaluation of transverse evenness is realized due to determination of the quality of road pavement from the aspect of permanent deformations, which are well-known as road rut [1]. By measurement of transverse evenness, following parameters are evaluated:

- **rut depth /RD/** - vertical distance between connection of apex wave and the lowest point of wave (Fig.3),
- **permanent deformations /PD/** - vertical distance between first and last point of measured profile and the lowest point of wave (Fig.3),
- **water depth /WD/** - vertical distance between horizontal flat ground in the position the lowest point of wave and the lowest point of wave (Fig.3).

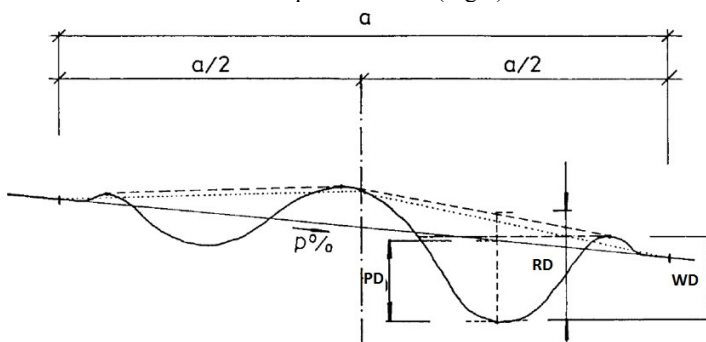


Fig.3 Rut depth.

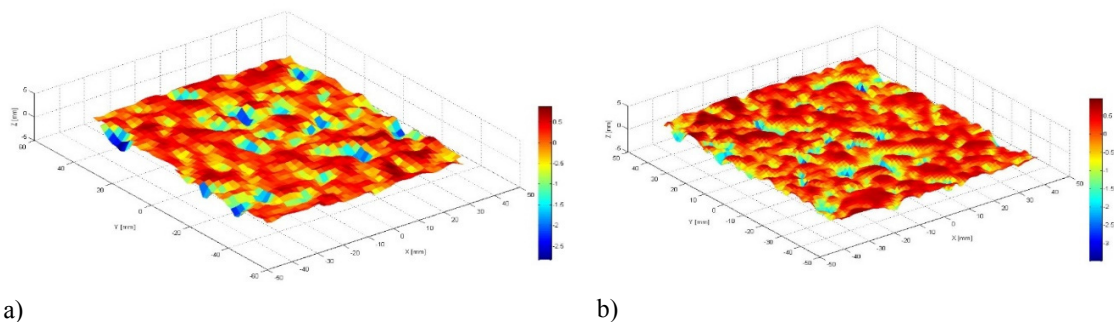
The creation of road ruts (Fig. 3) is as a result of mostly two dominant aspects; in the first case it is the over limited traffic load and excessive traffic density and in the second case, it is the parking and staying of heavy trucks on unassimilated pavement's surface – especially inappropriately elected surface [3,4,8]. For this reason, it is also very helpful to use the testing field to develop more details about the reason of creation of pavement ruts (Fig. 1).

3. Texture

Texture of pavement surface has a significance impact level on anti-skid features of the pavement, possibly the greatest. It is the morphological layout of material of the pavement surface. It is usually described by surface profile, which is defined by two coordinates. They are a combination of bumps described by wavelength (horizontal projection of bumps) and amplitude showing vertical projection of bumps in terms of given range. The surface texture influences plenty characteristics of car-pavement collaboration including friction by wet weather, noise, water spraying, rolling resistance, and tyre wear and damage of the car. In the point of view of skid resistance, microtexture and macrotexture have their special meaning [2]. Microtexture reflects prominences on aggregate grains, describes how the grains are smooth or rough and therefore raises the friction between tyre and pavement surface. It is characterized by wavelength range from 0.001 to 0.2 mm and amplitude range from 0.0 to 0.2 mm. Due to its range, impression of rough surface is created but microtexture is usually too soft to recognize it visually. Microtexture of aggregate surface issues elementary friction level and is important on dry surface by low speed up to 40 km/h. Another important meaning lies in an interruption of continual water film and creation direct contact of tyre with pavement surface [9]. Values of microtexture are partially influenced by the ability of aggregates to keep sharp edges and thus maintain rough surface, which should resist to smoothing caused by truck traffic at longest. Microtexture is partly dependant on the composition of an asphalt mixture as well as mineralogical structure of aggregates, maximum grain size, percentage of small aggregates, and content and type of asphalt binding [10]. Macrotexture of pavement surface is responsible for basic drain ability of pavement. It represents irregularities on pavement surface and describes a way in which single aggregate grains are ordered.

4. Analysis Of Measuring Data

The scale and accuracy of scanning are important for correct formulation of the requested level of texture and for implementation of scanned data. Scanning with the help of a 3D scanner enables formulation of surface in three proportions and therefore make complex information about the pavement surface available. To compare accuracy of the process, the scanning was done in four resolutions: 2, 1, 0.5, 0.2 mm. The values were selected with a view to potentialities of the device and to the macrotexture defined above.



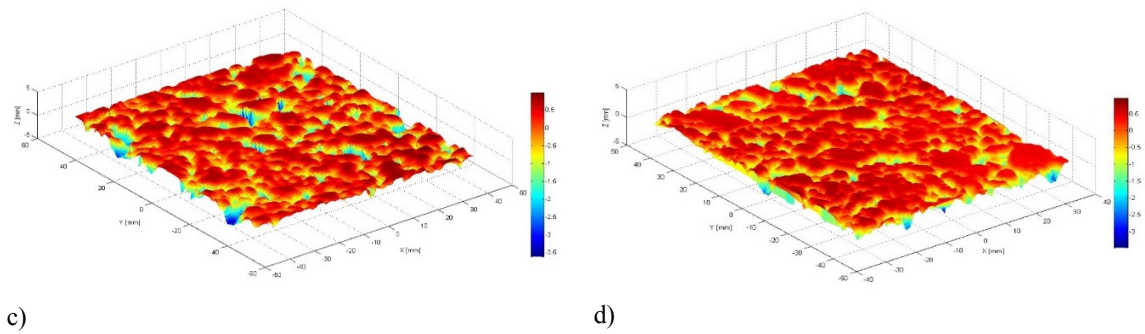


Fig. 4 The accuracy of the scanning surface.

From the scanned surface, profile by an elected resolution can be displayed. It is clear that increasing the accuracy of resolution scanning causes the profiles to show tinier projections. Appropriately chosen scan accuracy is important for further processing of the measured data [11]. Based on profiles from measured surface the mean profile depth (MPD) was calculated and it is used to represent state of surface macrotexture. The values of average depth profile are changing gradually with precision scanning. As the accuracy of scanning rised the MPD value also rised. When the accuracy was incremented by 0.1 mm, the MPD value incremented by 0.01 unit and dark columns are the scanned values. Measuring and monitoring the rut depth has similar approach as monitoring the pavement texture. The resolution scale in this case is 1 mm. The rut depth was monitored in driving path in initial state and then after about 25 000 cycles – the rut depth after this is about 1.5 mm (Fig. 5).

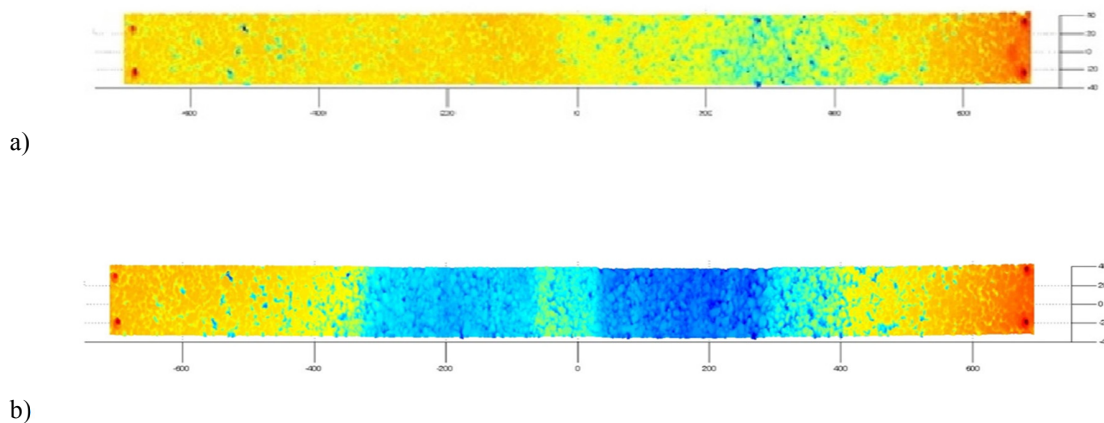


Fig. 5 The rut depth in initial state and after 25 000 cycles.

Scan unevenness is sufficient to scan at a lower resolution, seeing that the transverse unevenness is in the order of millimetre values. Scanning of cross section with a length of 1.6 meters and width of 8 cm was realized with the scanning resolution accuracy of 1 mm. For better determination of analyzed profile and mainly due to the relatively difficult lighting conditions, the measurement template were used in bounding observed cross section (Fig. 6).

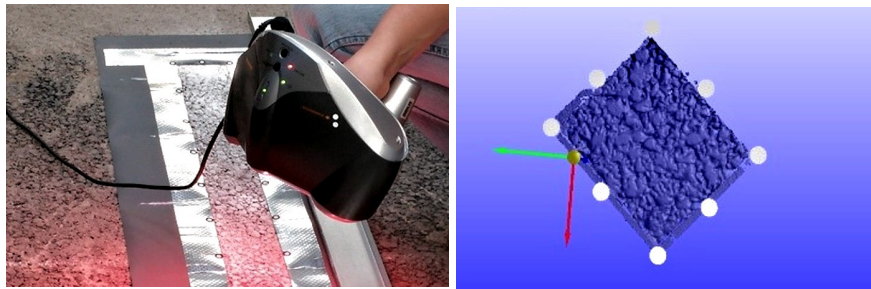


Fig. 6 Procedure of measurement and visualisation.

5. Conclusion

Laser scanning is currently from the time-consuming and economic point of view the most effective method for the measurement of spatial objects and the subsequent creation of 3D models from measured data. Laser scanning is highly suitable for monitoring changes in the surface properties of the road but also the natural activity (landslides) in real time. The result is a 3D scan cloud of points with the coordinates X, Y, Z, which makes three-dimensional image. It also points out the necessity of the further monitoring and analysing the above-mentioned parameters. They will create features, models that will later play an important role in the future predictions, thereby directly help to develop, and attempt to improve our road network. Thus the created prediction models and functions support the transport network administrator in the planning and optimization of operations such as maintenance, repair, rehabilitation and replacement transport network and its net asset value (roads, bridges, tunnels) the most effective way for the long term.

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